Chapter 6
DRAINAGE

Introduction

The NHDOT *Manual on Drainage Design for Highways* referred to as the "Drainage Manual" (8) is the approved guide for designing New Hampshire highway drainage facilities. This chapter includes a minimum of duplication from that manual plus general information useful to the designer.

Drainage design involves the hydraulic analysis, selection of drainage structures, and identification of Best Management Practices for temporary/permanent Erosion & Sediment Control measures, along with Water Quality Management. These procedures, hydraulic tables and charts are addressed extensively in State/Federal manuals which are not included in this chapter. This chapter will focus on the Department's guidelines and standard practices.

The NHDOT is strongly committed to prevent erosion and sedimentation from occurring and to protect water and other natural resources. See Appendix 6-1 for the policy statement.

Responsibility

Coordination

Responsibility for drainage design is shared by the Bureaus of Bridge Design and Highway Design. The separation of the responsibility is based upon size of the drainage structure. Bridge Design is responsible for structures 3.048 m (10 ft.) and over in span along with the structural analysis for concrete box structures regardless of size. Structures less than 3.048 m in span are designed by Highway Design.

Special drainage structures, retention/detention basins, energy dissipators, hydraulic inlets and the like are designed or approved by the Hydraulics Engineer and coordinated with Bridge Design as appropriate.

Close coordination between the Highway Designer and the Hydraulics Engineer is required if the highway drainage is complex or includes unusual drainage design elements. If routine, the designer should prepare layouts and computations for a cursory review by the Hydraulics Engineer, if appropriate, rather than request design assistance. If there is a question of responsibility or jurisdiction, the Highway Design Administrator will resolve it.

Survey and Field Information

Bridge Design will require roadway plans including layouts, typical sections and profiles from Highway Design to perform their work. Other information will be assembled by Bridge Design.

The designer should evaluate the following list of drainage concerns on their initial field review of the project and check with the Hydraulics Engineer to determine how much of this information is required, and if additional field information is needed:

- Drainage area(s) / type of ground cover(s);
- Condition of existing closed drainage system;
- Water mark elevations at existing drainage structures;
- Description of culvert structure - condition, type, and diameter;
- Description of channels upstream & downstream of structures including condition, bottom/sideslope characteristics, profile, typical section, and water marks and/or depth of water if encountered;
- Review existing contours to determine drainage flow paths and erosion areas;
- Identify seasonal flooded areas, wetlands, and excessive ground water (i.e. seeping backslopes/spring eruptions);
- Identify septic systems and wells; and,
- Check with Maintenance District(s) for history of drainage problems in the area.

Flood information, flood plain maps, photogrammetry, aerial photography, USGS topographic maps, storms of record and old project plans are usually on file in either Highway Design (Records Section and Hydraulics Section), Bridge Design or in Transportation Planning for mapping and graphics.

Permits

The New Hampshire Wetlands Bureau (NHWB) - Wetlands Permits are required for all work affecting and/or within their jurisdictional areas adjacent to or within natural water courses and wetlands. Early in the design process, the Bureau of Environment will make that permit determination on a project by project basis. For application procedures, the Designer should refer to the Department's *Permit Process Manual for NH Wetlands Bureau Permits* (4) and coordinate with the Bureau of Environment and/or the Hydraulics Engineer for guidance, review and distribution. The permit application process should begin immediately after the ROW plan stage.

U.S. Army Corps of Engineers (ACOE) Permits are required for all work affecting natural water courses and wetlands. Implemented June 1, 1992, the ACOE has issued to the State of New Hampshire a State Program General Permit (SPGP). Under this program, the ACOE grants the NHWB permission to act on their behalf for certain projects, with a follow-up concurrence notice from the ACOE. The ACOE, however, retains the right to require a project to go through their Individual Permit process. This decision is usually determined through the Bureau of Environment's Natural Resource Agencies (monthly) Coordination Meeting.

If an ACOE Individual Permit is required, coordination with the Bureau of Environment and the Hydraulics Engineer is necessary to develop the application. Both applications (ACOE & NHWB) are processed at the same time. To eliminate the duplication of effort, plans from the Individual Permit Application may be used in the NHWB Permit application. All permits and applications will be processed by the Bureau of Environment and the bureau that initiated the request.

The Individual Permit Application must be submitted early for review by the Hydraulics Engineer and the Bureau of Environment prior to distribution. The lead time to obtain an ACOE Individual Permit ranges from 3 months to 1 year depending on the type of wetland impacts on the project and the complexity of the project. The Bureau of Environment can provide an estimated time frame to receive the Permit.

As of October 1, 1992, the NHDOT is required to obtain the Environmental Protection Agency's (EPA) National Pollutant Discharge Elimination System (NPDES) Permit, with the Department of Environmental Services having NPDES delegated authority. The NPDES Permit regulates stormwater discharges in an effort to control and reduce non-point source pollution. Under this permit program, projects that have disturbance greater than 2.02 hectares (5 acres) or more, are required to obtain this NPDES permit. The disturbance area is determined by the overall project limits. The EPA's regulations require that the Contractor (with control of the day to day operations on the construction site) secure this permit. If the project falls under the above criteria, a "Special Attention" will be included in the contract Proposal alerting the Contractor that the NPDES permit is required. This Special Attention advises of the Contractor's responsibilities to implement the Best Management Practices (BMP's) to control pollutants for those stormwater discharges.

The designer will assist the Contractor in the application process for the Permit by providing information from the design phase. An Informational Sheet which provides this data, will be included with the Special Attention. Details of the Informational Sheet and Guidelines can be provided by the Specifications Engineer, (see Appendix 6-1).

Drainage Review and Approval

The Hydraulics Engineer, upon request, has the responsibility to review drainage criteria, methods of calculation, erosion control and water quality considerations for Highway Design as well as other Bureaus/agencies that request this assistance.

The criteria and procedures are generally described in the Drainage Manual. If there are questions regarding the approach to a particular design, consult the Hydraulics Engineer.

Guidelines and Procedures

These guidelines and procedures include Storm Frequency for Design; Runoff Computations; Designs of Culverts, Storm Sewers, Ditches, Slope Drainage and Underdrains; and, Stormwater Management, Erosion & Sediment Control and Water Quality issues.

In addition to the guidelines describing elements of drainage design, the designer should be aware of the following general concerns:

- Drainage items, on the average, account for 20 to 30 percent of the cost of highway construction (which includes Stormwater Management and protective measures).

- Inadequate drainage design can cause damage to property, environmental impacts, injuries, and possibly result in litigation. Attention is needed to control the outflow of highway drainage.
- Erosion control and runoff pollutant removal is a major factor in determining the success of a design.
- Water rights are often the subject of legal disputes. Natural streams should be preserved and not diverted. In addition, downstream effects of all outlets must be evaluated.
- Coordination with appropriate agencies is mandatory such as with, but not necessarily limited to:
  - U.S. Army Corps of Engineers
  - New Hampshire Department of Environmental Services
  - New Hampshire Wetlands Bureau
- The designer is responsible for the drainage design. Use the Drainage Manual as the approved reference and consult the Hydraulics Engineer as necessary.
- Maintenance concerns

Runoff Computations

Procedures for developing runoff computations and design storm frequencies are explained in the Drainage Manual.

Storm Design Frequency

The frequency of the design year storm has no relationship to the design year of the highway improvement. The design year development of the watershed area will be considered in the runoff computations.

Rainfall is classified by probability of occurrence, commonly called 10, 25, 50, or 100-year frequency storms. A 100-year storm has 1:100 chance or a 1 percent chance of occurring in any particular year. A 50-year storm has a 2 percent chance of occurring in any particular year. Hence, a 25 or 10-year storm has a 4 percent or 10 percent chance, respectively, of occurring in any particular year. This designation is to classify heavy rainfall events, but it does not mean a 100-year storm will occur only once or if at all in 100 years.

The intensity of a storm is measured in mm/hr. The intensity of a 50-year storm will be greater than the intensity of a 10-year storm in the same location. The intensity of a storm will vary with its duration, other factors being similar. The average rate of rainfall for a storm 10 minutes long will be greater than the average rate of rainfall for a storm 1 hour long of the same frequency.

Conceptual drainage design must be performed during the Preliminary Design stage. Design frequency criteria affects the size of culverts, and along with the required minimum cover, may affect the roadway profile and, therefore, may be an important control. Provisions for stormwater runoff treatment areas (i.e., vegetated treatment swales, sedimentation basins) must also be considered in the Preliminary Design stage. The Engineering Report should mention where drainage is a control factor. Final design of projects requires documentation for all culverts. Computation methods are shown in the Drainage Manual.

Detention Basins

There are conditions when it is desirable to detain the runoff before it enters the culvert, storm sewer or stream. A detention basin is sometimes used to store storm-water runoff until the outlet pipe can release it or until the receiving water course can accommodate it, similar to a flood control dam.

The most common reason to consider using a detention basin is to limit the volume of water downstream which, in turn, provides a side benefit of reducing the size of the downstream pipes and structures. As an example, a safe headwater upstream from a highway may dictate the use of 1000 mm pipe. However, a detention basin could provide temporary storage until a 300 mm pipe will empty the basin after the storm.

Detention basins should be fully drained within a day after the storm. If they are in urban areas or could be classified as an attractive nuisance or safety concern, they should be enclosed with fence or be designed as an underground system.

Other considerations include the cost of the land and effect on the environment. Thorough studies must be made of the comparative costs. In some cases, several alternate drainage designs with variations can achieve the storage requirements.

All hydraulic characteristics of the system should be considered. The basic tools for the design of a detention pond are the Inflow Hydrograph (unit-hydrograph; a watershed's rainfall-surface/runoff relationship plot that indicates "Discharge versus Time"), the pond's Stage-Discharge, and Stage-Storage relationship. These three (3) components are necessary to establish the pond's storm containment and rate of desirable outflow (Inflow-Storage = Release Rate). The Soil Conservation Service (SCS) TR-55 is the drainage design methodology that should be used to obtain the three (3) components necessary to design a detention pond for a 24 hour storm event.

If the designer believes the detention basin method has application, contact the Hydraulics Engineer and explain the conditions. The Hydraulics Engineer will prepare information suitable to request a decision from the Highway Design Administrator.

Sedimentation basins may also be considered for design. The purpose of sedimentation basins is to collect sediment or other waterborne pollutants. They are intended for temporary use during construction, but should be designed using the same criteria as for detention basins.

Storm Sewers

Control of Flow

Within urban areas, storm-water runoff collected in the roadway normally will be controlled with curb and gutter sections and will discharge through a storm sewer system.

Urban-area drainage systems should limit the water ponding along the curbline and behind the curbs to amounts that will not interfere with traffic or damage property. This is accomplished by placing catch basins, or drop inlets, at low points and intervals determined by gutter flow and grate inlet capacity.

The minimum size pipe to be used for various conditions are given in the Drainage Manual. The designer should check with the municipality (if appropriate) for minimum pipe size and strength requirements if the maintenance responsibility is not to be assumed by the NHDOT.

Runoff Discharge Tabulation

Orderly tabulation of the runoff discharge computation is essential to facilitate the storm sewer design. Sample worksheet forms are provided in the Drainage Manual.

Sizing Storm Sewers

With the tabulated discharges, refer to the charts from the Drainage Manual to determine the pipe size necessary for the allowable gradients. Storm sewer line gradients should be generally similar to the roadway grade. The same size of pipe will run until the cumulative discharge approaches the pipe capacity during the design year storm. When an abrupt reduction in gradient is encountered, an increase of more than one pipe size may be required. Never reduce the pipe size when an abrupt increase in gradient is encountered.

The hydraulic gradient is the line of elevations to which the water would rise in successive piezometer tubes along a storm-sewer run. Differences in elevations for the water surfaces in the successive tubes represent the friction loss for that length of storm sewer. The friction slope is the slope of the line between the water surfaces.

The storm sewer run will not be under pressure if it is placed on a calculated friction slope corresponding to a certain quantity of water, cross section, and the pipe's roughness factor. The resultant hydraulic gradient will be parallel to and at an elevation equal to or lower than the top of the pipe. This is the desirable condition.

There may be reason to place the storm sewer run on a slope less than friction slope. In that case, the hydraulic gradient would be steeper than the slope of the storm-sewer run. Depending on the elevation of the hydraulic gradient at the downstream end of the run, it is possible to have the hydraulic gradient rise above the top of the pipe, creating pressure on the storm sewer system until the hydraulic gradient at some point upstream is once again at or below the top of the pipe.

A hydraulic grade line is the actual water surface elevation within the storm sewer system for a given design year storm.

Computation of the hydraulic grade line of a storm sewer run will not be necessary where:

- The slope and pipe sizes are chosen so that the slope is equal to or greater than the friction slope.
- The top of successive pipes are aligned at changes in size (rather than inverts being aligned).
- The surface of the water at the point of discharge does not rise above the top of the outlet.

The pipe will not operate under pressure in these cases, and the slope of the water surface under the capacity discharge will approximately parallel the slope of the pipe invert. Small head losses at inlets and manholes may be disregarded if these structures are properly designed.

In cases where a pipe discharges against a head or when it is desired to check the storm sewer system against larger than design floods, it will be necessary to compute the hydraulic grade line of the entire storm system. Begin with the tailwater (TW) elevation at the storm sewer outfall and proceed upstream the length of the storm sewer. For every run, compute the friction loss and plot the elevation of the total head at each manhole and inlet.

If the hydraulic grade line does not rise above the top of any manhole or above a basin grate, the storm sewer system is satisfactory and provides some measure of fluctuation. If it rises above these points, surcharging (overflow) may occur through the manhole covers and basin grates. Pipe sizes or gradients should be increased to eliminate surcharging within the structures.

A hydraulic gradient must have an original base elevation above the outlet tailwater elevation.

Most drainage design manuals describe hydraulic grade line computations. If more information is required, consult the Hydraulics Engineer.

Ponding Limits on Roadway

Water flow along the curb line should be confined to a width and depth that will not affect traffic flow. The ponding width will have a corresponding depth and the quantity of water carried will depend on the curb line profile, roughness coefficient, roadway cross slope, inlet spacing and capacity.

The recommended limit of ponding is within the paved shoulders (2.4 meters to 3 meters). In sections with no paved shoulders or paved shoulders less than 2.4 m, ponding limits must not encroach beyond one-half the traveled way in either direction of travel.

Charts in the Drainage Manual (open channel series)are used for curb line and median capacity design. With given restraints on ponding, determination can be made of the allowable accumulated runoff discharge that the curb line can accommodate. This, with the basin's grate capacity, will indicate the required spacing of inlets.

Catch Basins and Drop Inlets

Drop inlets do not have sumps and are used to pick up flow from the roadway surface with no contributing pipe inletting into the structure (commonly used for slope pipe applications), however catch basins that do have sumps are most frequently used since the sump provides storage for sediment. The maximum pipe size entering or leaving a standard 1.2 m diameter catch basin, drop inlet or manhole is a 750 mm diameter CMP or 600 mm diameter RCP. Larger pipes will require a larger structure (refer to the Drainage Manual for sizing requirements).

Underdrain

The purpose of underdrain is to remove ground water in order to ensure a stable roadbed and side slopes. Frost heaving, seeping backslopes, and spring eruptions are three of the more obvious indications of excessive ground water. Ground water infiltration is not significant enough to be considered as part of the storm sewer design in terms of the additional quantity of water contributing to the drainage system; however, known spring and well locations should be identified on the plans. The Geotechnical Report recommends where underdrain should be located within the project. There are times, however, when water bearing formations are not revealed until construction has begun. (See the standard plans for underdrain cover requirements).

Note: Specification Section 605 provides information on the types of underdrains approved for use.

Culverts

The design of a culvert begins with the determination of the design discharge to be accommodated. There are Drainage computer programs available for culvert design. When a number of culverts are to be designed, the computer method is the most efficient. The Hydraulics Engineer can provide the designer with the appropriate computer program/method and assist the designer in using it. The culvert's design location must be aligned to minimize impacts to the natural channel wherever possible.

If conditions are such that a box culvert or small bridge is the best alternative, the Hydraulics Engineer should be consulted before proceeding with more detailed design.

Type, size, strength requirements, location, pipe material, and environmental issues are important elements of culvert design. All are described in more detail on the following pages.

Type

The selection of the type of pipe for driveways and underdrains usually are the Contractor's option. The following are the types of pipe, in order of preference, that should be specified:

1. Single circular pipe hydraulically efficient for the design Q,
2. Single pipe arch hydraulically efficient for the design Q, or

3. Double or two-cell combination circular pipes hydraulically efficient. (More than two cells should not be considered under most circumstances unless reviewed and approved by the Section Chief.)

If any of the following conditions are evident, reconsider your first choice and consult the Hydraulics Engineer.

- Consider upstream debris, which may warrant a trash rack or the use of twin pipes.
- Corrosion potential due to the stream's pH level.
- Consider bedding conditions, height of fill or lack of cover. If soil conditions are poor or for any reason disjointing might occur, a steel pipe with rigid fastened couplings may be a better option.
- Consider difficulty of construction, access, or temporary drainage needs.

Specification Sections 591 and 603 provide information on the types of culverts and storm sewer pipe approved for use.

Strength Requirements

Culverts must be designed for impact loads resulting from minimum cover conditions and for weight of embankment under high fill conditions. Where fill height is 6 meters or greater Imperfect trench construction must be used provided in the Standard Specifications 603.3.6.

The width of the trench must never exceed what is specified in the Standard Specifications, wider trenches may necessitate a higher strength pipe.

The Height-of-Cover Tables in the Drainage Manual contain information needed to designate the strength requirements for culverts under various heights of fill. The requirements are based principally on the size and shape of culverts, the amount of cover over the pipe and, in some instances, the class of bedding and type of backfill.

The Standard Specifications provide for two (2) methods of culvert bedding.

- Specification 603.3.2.1 - Bedding for pipes less than 1200 mm in diameter.
- Specification 603.3.2.2 - Bedding for pipes 1200 mm or more in diameter.

The standard bedding procedure for pipe in bedrock consists of bedding the pipe on a prepared layer of sand at a depth of 300 mm and backfilled as defined in the Specifications with the material uniformly compacted.

Refer to Section 603. - Supplemental Specification installation of bedding for Plastic pipe.

Additional information regarding structure excavation can be found under Specification Section 206 which also shows pay limits for culvert excavation.

Location

The most desirable location hydraulically is in line with the natural stream but economically should be as close to perpendicular to the road as possible. This desirable location is both economical and hydraulically efficient.

Wherever possible, culvert installations should be designed to conform as closely as possible to natural drainage channels. The length of pipe should not be compromised. If a skewed alignment is needed to fit a natural water course (because relocation is not feasible), then, it should be used. The cost associated with stream relocation, erosion control or damage caused by erosion, environmental effects and channel protection may be more of a construction cost than that of the additional length of pipe required for the skewed installation.

The degree of skew is measured as the angle between the pipe installation and a line perpendicular to the highway centerline. Standard skewed end structures (headwalls) should be used, matching the skew of the culvert as closely as possible.

The required length of perpendicular culverts is determined by plotting the installation to scale on a cross section, and measuring the plotted lengths. For skewed installations, plot the pipe ends on the cross sections matching the proposed sideslopes, transfer the end locations by station and offset to the plan, then scale the skewed length from the plan and adjust for slope as necessary.

The length of pipe culverts should be estimated and recorded to the nearest multiple of 0.6 m.

Culverts have hydraulically limited lengths at which point their flow characteristics change. Long culverts (60 meters) should be checked by the Hydraulics Engineer.

Environmental Issues

The area adjacent to the culvert plays a key role in the design/selection of a culvert. The designer needs to be aware of issues such as impacting wetlands, disrupting plant and wildlife habitat, and provide adequate openings for fish passage. These issues normally are identified by the Bureau of Environment early in the design stage and should be coordinated accordingly.

Other considerations include maintaining water quality by preventing erosion and sedimentation downstream. The transport of phosphate-bearing sediments can be detrimental to the waterway. Phosphates can cause a significant increase in algae and other plants. This effect can potentially alter the ecology of the stream. Silt fences and turbidity curtains may be used during construction and should be accounted for in the design process. The designer must also consider stone outlet protection and or velocity reduction to prevent downstream erosion and damage to property.

Outlet protection is a major concern in the culvert design process for water quality issues (high velocities will cause soil erosion and sediment/turbidity in the area downstream), and also for the protection of the surrounding soils and pavement structure. The need for protection will be determined by calculating the exit velocity and checking to ensure that it is lower than the permissible velocity for the composition of the stream bed. If stone outlet protection is required, the amount and size of stone will be determined by the discharge, channel slope, and tailwater depth at the outlet.

Culvert End Treatments

There are many types of culvert end treatments. Refer to the Standard Plans for details. It is particularly important that the end treatment does not become a hazard within the clear zone.

Pipe End Section vs. Header

Culvert inlets at active waterways (year-round & seasonal streams/brooks) and those culvert outlets under outlet control (tailwater condition) must always have headers. End sections are typically used at culvert inlets/outlets when not operating under headwater or tailwater conditions.

Types of headers and application:

- Concrete headers:
  - Submerged inlets or outlets
  - Active waterways with the potential for ice build up.
  - Salt water areas (special concrete, e.g., microsilica to be used to minimize concrete deterioration)
- Mortar Rubble Masonry (MRM) headers:
  - Areas that are within Public view
  - Areas within Historic Districts
  - Areas where aesthetic appearance should be considered

Type of end sections and application:

- Concrete end section:
  - Pipes that are no greater than 1200 mm in diameter
  - Areas that are within Public view
  - Urban areas
  - Areas with abnormally low pH
- Steel end sections:
  - All steel pipes
  - At concrete pipe outlets where a concrete end section or headwall is not used. When used on concrete pipes, the end section shall be sized one size greater than the pipe size (i.e. 375 mm RCP pipe uses a 450 mm steel end section).

- Metal end sections:
  - All metal pipes (typically drive pipes & slope pipes which are the Contractor's option)
- Plastic end sections:
  - Sized the same as steel end sections. Although HDPE (High Density Polyethylene) plastic end sections are available, the NHDOT has not used them. With the onset use of plastic pipe, this practice may change, and plastic end sections may be approved for use.

With regard to safety, end sections (600 mm or smaller) along the slope are preferred because an errant vehicle can drive across them. Headers may constitute a hazard for the errant vehicle even if outside of the clear zone.

Improved Culvert Entrances

In conditions of inlet control, improved entrance structures can increase efficiency and/or reduce the required culvert size. Improved entrance structures on existing culverts may increase the culvert capacity sufficiently to accommodate increased discharges from land-use development. This treatment is usually considered when the hydraulic conditions are appropriate, the culvert's structure requirements are not diminished, and it proves economically justified compared to culvert replacement.

Improvements at pipe and box culvert entrances include beveled entrance edges and special-design entrance structures. Hydraulic Engineering Circular No. 13, *Hydraulic Design of Improved Inlets for Culverts* (21), shows design procedures. Normally, this design is performed by the Hydraulics Engineer.

When the culvert is operating under outlet control conditions (the culvert's tailwater elevation is higher than its headwater elevation) at design discharge, the culvert entrance improvements would be of no advantage. When the culvert is operating under inlet control conditions (the culvert's headwater elevation is higher than its tailwater elevation), entrance improvements should be evaluated. Computer programs for designing improved entrance structures are available.

Flow Control

The control of flow is a major concern of the designer. With the considerations necessary for erosion and sediment control, and impact to properties, the energy and volume of flow must be controlled to minimize the undesirable effects which would otherwise result.

The preferred area to control the flow is before it outlets the drainage system. Supercritical flows (high velocity, low depth) can be reduced to subcritical flow (low velocity, high depth) by forcing a hydraulic jump within the system. At low velocities, the runoff is not as likely to erode soil and any sediment present will be more likely to settle out than at higher velocities. Some methods by which this may be done is as follows:

1. Pipes with higher roughness coefficients;
2. Flat pipe grades;
3. Energy dissipation within the pipes;

4. Detention basins within the system to meter flow;
5. Elevation drops through drainage structures; and.
6. Increase pipe capacities within the system for use of flow regulators.

The above methods may not be practical in certain situations or may not have the ability to achieve the desired result. If so, flows can be controlled at the outlet by distributing runoff over a wide area to reduce the velocity, using impact structures to physically block free discharge thereby creating an energy loss, or by forcing a hydraulic jump as described above. The following treatments at the outlet are options where slope and area are appropriate:

1. Outlet ditch protection such as stone lining;
2. Rip-rap basins;
3. Rigid boundary energy dissipators;
4. Baffle wall energy dissipators;
5. Stilling wells;
6. Sedimentation basins;
7. Detention/retention basins;
8. Level spreaders;
9. Treatment swales;
10. Stone check dams; and,
11. Outlet onto flat channel grades for increased tailwater.

Open Channels (Ditches)

Open water courses 3 m or more in width are called "channels". If less than 3 m in width, they are called "ditches." Channel design must always be coordinated with the Hydraulics Engineer.

Highway ditches, concave (depressed) medians, gutters, and relocated water courses are treated as open channel flow for design purposes and normally coordination with the Hydraulics Engineer is not necessary. Channels in the vicinity of bridges are designed by Bridge Design. Most other open channels are designed by Highway Design.

Size and Shape

Trapezoidal channels are usually the most economical.

Under average conditions, side slopes ranging from 2:1 to 3:1 are satisfactory. The side slope of a ditch contiguous with the roadway slope should be a continuation of the normal roadway slope. In areas where mowing will be necessary, the side slopes should be designed at a 4:1 slope or flatter.

Capacity Computations

In general, ditches or channels flowing to or from culverts are designed using the same storm frequency, velocity and depth of flow compatible with the culvert. Other (permanent) ditches are usually designed to accommodate a 10-year storm. Temporary ditches are designed to accommodate a 5-year storm. The designer should investigate potential damage from a greater storm for all ditches and channels.

Alignment and Grade

Changes in channel alignment should be gradual. The radius of horizontal curvature measured along the centerline of a channel should be at least 3 times the bottom width of a trapezoidal or rectangular channel. The minimum grade to be used is 0.25 percent.

When relocation of a stream becomes necessary, maintain the characteristics of the existing stream, i.e., grade, alignment, and roughness.

Erosion Protection

Channel protection may be required to prevent erosion and sediment deposition downstream. The need for ditch or channel protection will be determined by the velocity of flow. Depending on the type of ditch or channel bed, protection may be necessary when permissible velocities for the vegetation and underlying soils are exceeded.

Common practice for control is to use matting with hay mulch, stone lining with geotextile matting and, establishing a good stand of vegetation before much of the contributing site is cleared. Such measures provide slope protection where practices such as silt fence, stone check dams, log check dams, and well-established dense vegetation provide flow reduction and sediment filtering. These are only a few of the possibilities available for channel protection. More elaborate and costly protection may be required for higher velocities.

Refer to the Drainage Manual and other State/Federal manuals, as listed under the section titled "Erosion Control", for Best Management Practices to determine the extent and type of protection to be used. Check the permissible velocity and roughness coefficient for the various types of protection.

Median Drainage

For medians between widely separated roadways (in excess of 27 m), adequate drainage is provided by culverts under the roadway. With narrow medians, it is usually necessary to provide intermittent catch basins, ideally located coincident with the culverts; however, separate median drain outlets should be included where needed.

Median drains must be placed at the low point of sag vertical curves. The reach in either direction is critical for sag inlets. Special care must be used to limit ponding.

Median Drain Spacing

For divided roadway sections with graded medians, median drains should be spaced to result in no greater than 300 mm depth of flow for the 10-year rainfall. Although the median ditch may have a greater capacity on steeper grades, drain spacing distances should be coordinated with culverts.

Erosion Control

Temporary and Permanent erosion and sediment control measures and their criteria are discussed in the Drainage Manual.

The designer should be familiar with the various Best Management Practices (BMP's) for temporary and permanent applications. Coordination with the Hydraulics Engineer along with the Bureau of Construction is necessary to provide for the project's Stormwater Management Plan and Water Quality Protection. During the preliminary design stage, prior to the Public Hearing, BMP's and water quality issues need to be addressed so that adequate Right-of-Way is acquired to implement the BMP for that site. Under the final design stage, permanent BMP's are shown on the Plans, included in the Estimate, and discussed in the Prosecution of Work. Temporary BMP's during construction are the responsibility of the Contractor and is covered in the contract under Item 645.7 - Erosion and Sediment Control Stormwater Management Plan, Item 645.71 - Monitoring Erosion and Sediment Control, and Item 699 - Temporary Project Water Pollution Control. However, the designer must anticipate what temporary BMP's will be needed, and whether items within the contract can address those needs for temporary erosion and sediment control use. The purpose of Items 645.7 & 645.71 is to develop a Stormwater Management Plan for the project and implement a monitoring program during construction.

Items provided for use in implementing temporary BMP measures are as follows:

Item.585.3 - Stone Fill, Class C
Item 593.1 - Geotextile, Woven
Item 593.2 - Geotextile, Non-Woven
Item 645.2 - Matting for Erosion Control
Item 645.251 - Special Matting for Erosion Control, Type I
Item 645.252 - Special Matting for Erosion Control, Type II
Item 645.51 - Hay Bales for Temporary Erosion Control
Item 645.531 - Silt Fence
Item 645.532 - Silt Fence with Support Fence
Item(s) 646.1 & 646.11 - Turf Establishment with Mulch
Item 699. - Temporary Project Water Pollution Control

Water Quality

Preserving the quality of receiving waters for stormwater runoff is an increasingly important factor in drainage design. This is accomplished by trapping or filtering all nonpoint source pollution (contaminants which are washed across land and road surfaces by rain and snowmelt). A variety of BMP's have been developed to remove pollutants from runoff. Each has a different level of effectiveness for the site and type of pollutants present in the runoff. Some commonly used practices include the following:

Vegetated treatment swales - channels which are constructed with dense vegetation for filtering out pollutants from runoff and increasing infiltration. Treatment swales are most effective when the vegetative lining and channel geometry (cross-section and slope) reduce the flow velocity to 0.30 m/s or less. If this result can be accomplished by outletting into a naturally vegetated channel, the additional cost and impact of a constructed swale is not necessary. This is especially important near a waterway, where fertilizer required for new vegetation can wash into the receiving water body as a pollutant.

Vegetated filter strips - vegetated panels on gradual to moderate slopes which treat sheet flow by reducing runoff velocity thereby allowing the vegetative lining to remove contaminants from runoff. Naturally covered areas may be used if adequate and uniform vegetation is present. Filter strips should be wide enough for thorough treatment and flow must be distributed equally to prevent runoff from concentrating and forming rills.

Level spreaders - flat (0% grade) outlet trenches which are constructed to change concentrated pipe or channel flow into sheet flow. The runoff is released over the lip of the spreader as a thin, evenly-distributed layer onto an erosion-resistant vegetated slope for treatment. The spreader will be vegetated for erosion control. Treatment will occur when the flow exits the spreader.

Sedimentation basins - as previously described, are an effective measure for settling material from stormwater runoff and releasing water at a controlled rate so not to cause disturbance to waterways downstream. Basins require periodic cleaning (The sediment volume should never exceed one-half of the original storage volume). The sediment removed from the basin must not be discarded adjacent to a waterway or flood plain or where it will erode from the site.

Retention basins - pools designed to have permanent standing water with temporary storage of stormwater runoff. Retention basins improve water quality in several ways, some of which include: trapping sediments, heavy metals, and bacteria. They also provide a pool in which infiltration and some chemical and biological changes can occur. The forebay of the pond allows wetland plants to be established in which pollutants will be removed, and the outlet structure controls the rate of release into downstream channels to minimize impacts.

Refer to the "*Stormwater Management and Erosion and Sediment Control Handbook for Urban and Developing Areas in New Hampshire*" (22) for application and design of previously described and additional BMP's. A variety of manufactured products have been created for additional water quality protection or can be used when land is not available for vegetated BMP's or a basin for treatment is not practical. Such technologies include oil/water separators, detention/infiltration chambers, and artificial vegetated treatment basins. The Hydraulics Engineer can provide more comprehensive information on these and other stormwater technology products.

All treatment techniques may require regular maintenance. No treatment alternative should be used in lieu of proper erosion control measures, i.e., stone outlet protection, energy dissipators, rip-rap basins, and good construction planning, but shall be implemented to achieve protection of the abutting natural waterways. Drainage outlets and land grading should divert flow so as not to overtax any one treatment facility.

APPENDIX LIST

NEW HAMPSHIRE DEPARTMENT OF TRANSPORTATION

EROSION & SEDIMENTATION CONTROL AND STORMWATER MANAGEMENT POLICY

The New Hampshire Department of Transportation (NHDOT) is environmentally conscientious and strongly committed to the prevention of erosion and sedimentation and to the protection of water and other natural resources.

*It is the **policy** of the NHDOT to:*

- Meet or exceed State and Federal environmental laws and regulations
- Incorporate state of the art erosion/sedimentation controls and stormwater management measures into the design of its projects
- Ensure erosion/sedimentation controls and stormwater management measures are properly implemented and maintained during construction
- Properly maintain erosion/sedimentation controls and stormwater management measures after project construction
- Be vigilant in identifying and addressing erosion/sedimentation and stormwater concerns in the State/Federal transportation system
- Support and provide continuing education for all appropriate personnel
- Empower Department Contract Administrators and other supervisory personnel to enforce this policy

Leon S. Kenison, Commissioner

Carol A. Murray, Asst. Commissioner

April 22, 1999